OIPE JC148 JUL 2 8 2003 PATENT & TRADEMARK OFFICE

#19 Priority Papers
GMW 8-8-03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of

OBERG et al — Atty. Ref.: 2466-69

Serial No. 09/643,993 — Group: 2633

Filed: August 23, 2000 — Examiner: Tran, Dzung D.

For: PROTECTION OF WDM-CHANNELS

* * * * * * * * * * *

July 28, 2003

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

SUBMISSION OF PRIORITY DOCUMENTS

It is respectfully requested that this application be given the benefit of the foreign filing date under the provisions of 35 U.S.C. §119 of the following, a certified copy of which is submitted herewith:

Application No.	Country of Origin	Filed
9800545-7	Sweden	24 February 1998
9801642-1	Sweden	12 May 1998

Respectfully submitted,

NIXON & VANDERHYE P.C.

By: ______________________
Joseph A. Rhoa
Reg. No. 37,515

JAR:caj
1100 North Glebe Road, 8th Floor
Arlington, VA 22201-4714
Telephone: (703) 816-4000
Facsimile: (703) 816-4100

PRV

PATENT- OCH REGISTRERINGSVERKET
Patentavdelningen

PATENT ~ OCH REGISTRERINGSVERKET

Intyg
Certificate

Härmed intygas att bifogade kopior överensstämmer med de handlingar som ursprungligen ingivits till Patent- och registreringsverket i nedannämnda ansökan.

This is to certify that the annexed is a true copy of the documents as originally filed with the Patent- and Registration Office in connection with the following patent application.

(71) Sökande *Telefonaktiebolaget L M Ericsson, Stockholm SE*
Applicant (s)

(21) Patentansökningsnummer *9800545-7*
Patent application number

(86) Ingivningsdatum *1998-02-24*
Date of filing

Stockholm, 2003-07-14

För Patent- och registreringsverket
For the Patent- and Registration Office

Hjördis Segerlund

Hjördis Segerlund

Avgift
Fee 170:-

PATENT- OCH REGISTRERINGSVERKET
SWEDEN

Postadress/Adress
Box 5055
S-102 42 STOCKHOLM

Telefon/Phone
+46 8 782 25 00
Vx 08-782 25 00

Telex
17978
PATOREG S

Telefax
+46 8 666 02 86
08-666 02 86

SEL/CS 37666

Telefonaktiebolaget L M Ericsson, ref. ETX97-601

Inventors: Magnus Öberg, Jonas Hemgren

PROTECTION OF WDM-CHANNELS

TECHNICAL FIELD

The present invention relates to a method of protecting individual length channels in a WDM link, ring or bus network in the case of a transmitter, transponder or receiver failure, and to a node used for such protection and also a network in which at least one link is protected.

BACKGROUND OF THE INVENTION AND STATE OF THE ART

In telecommunication optical fibres have been used for several years, primarily owing to their large reliability, their insensitivity to electrical interference and their high capacity. Of course, there is a desire in the existing telecommunication networks to use the available optical fibres in their networks as efficiently as possible, in particular for communication over long distances, since such fibres obviously have high installation costs. By introducing wavelength division multiplexing WDM in existing communication systems using optical fibres a plurality of individual wavelength channels can be transmitted on the same optical fibre and thus the information transmitted over the fibre can be multiplied. Thus the need for installing more optical fibres can be postponed. Also, the telecommunication operators of course want to utilize their existing transmission equipment if possible also when changing to WDM systems or at least to utilize their existing equipment to the highest possible extent.

When using WDM in a link built of a single optical fibre pair between two nodes all information from one node to the other one will be transmitted at each instant over on one of the fibres of the pair. Because of the very large information amount transmitted over the fibre pair, a break-down of such a link will be extremely embarrassing. Thus, the ability of a network to restore communication or traffic on a failed link is very important. Protection must be built into links and networks using optical fibres carrying several WDM channels on optical fibres therebetween. Typical devices, in which failures can arise are of course the fibres themselves which can be cut off and the components in the transmission and receiving equipment.

In U.S. patent No. 5,299,293 a protection arrangement is disclosed which can be used in a WDM network. For the case of a faulty electrooptical transmitter, the input signal of the transmitter is coupled to the input of a spare transmitter through a n:1 electrical switch. The spare transmitter includes a tunable laser adapted to transmit the signal on the same wavelength as used by the defective transmitter. In U.S. patent No. 5,457,556 equipment for protecting optical communication to failures of the WDM equipment are disclosed. The published German patent application 44 33 031 discloses redirection of the information flow in an optical line to another line when the first line gets defective. In U.S. patent No. 5,218,465 is described how traffic for some failure can be redirected to another redundant path. A cross-connect switch receives all the input signals and is controllable to switch each signal to the redundant path.

In Swedish patent application No. 9602005-2, "Kanalskydd i data- och telekommuni-

kationssystem", an optical fiber network is disclosed using WDM, in which each node comprises at least one standby electrooptical transmitter and at least one standby optoelectrical receiver. A spare wavelength is used by the standby transmitter and receiver. The network is the bus type having traffic circulating through the node, in which the nodes tap off and/or add WDM channels as required.

DESCRIPTION OF THE INVENTION

It is an object of the invention to provide an optical link having protection, in particular an optical bidirectional link forming or being part of an optical network.

It is a further object of the invention to provide an optical link and nodes to be used in the link having protection working for many cases of different failing components.

It is a further object of the invention to provide nodes in an optical link having protection which can be built from standard components of a relatively robust type, not requiring e.g. tunable lasers.

In a protection arrangement for optical transmitter devices and receiver devices in nodes connected by a bidirectional link in a WDM network, a switch is arranged so that when one of the transmitter devices fails, its input signal is connected to a standby transmitter, so that this transmitter forwards the signal on a wavelength not used by the other transmitters. The optical transmitters and receivers of a node of such bidirectional link can be duplicated, a spare optical transmitter and a spare optical receiver being arranged as standby for each ordinary optical transmitter and each ordinary optical receiver. Transponders can be connected to receive the signals to be issued on an optical fiber connecting the nodes, converting the received optical signals to optical signals of well defined wavelengths. The output signals of the transponders are combined in an optical signal combiner or multiplexer and therefrom issued on the optical fiber. In each node, only one spare transponder is arranged as standby for the other, ordinary transponders. By arrangements comprising optical switches and/or optical couplers the optical signals from an ordinary optical transmitter or a spare optical transmitter can be forwarded to the spare transponder and issued thereby on a wavelength separate from the wavelengths used by the ordinary transponders.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in detail by way of non-limiting embodiments with reference to accompanying drawings in which:

Fig. 1 is a block diagram of a bidirectional WDM link having no protection,

Fig. 2 is a block diagram of a first embodiment of a bidirectional link having protection,

Fig. 3 is a block diagram of the same link as shown in Fig. 2 but illustrating the traffic paths after restoration caused by failure of a transponder,

Figs. 4 - 8 are block diagrams of further, different embodiments of a bidirectional link having protection,

Figs. 9 and 10 are block diagrams of 4:1 optical switches of hybrid type, and

Fig. 11 is a block diagram of a hybrid type, cross-bar optical switch.

DESCRIPTION OF PREFERRED EMBODIMENTS

In Fig. 1 a bidirectional WDM link having no protection is illustrated. The link comprises two add and drop nodes 1 connected by one fibre 3 for traffic in a first direction and one fibre for traffic in the opposite direction. The nodes 1 comprise in the embodiment shown three access equipments 5 for three electrical channels, each access equipment 5 comprising a transmitter (Tx) 7 and a receiver (Rx) 9. In the general case N access equipments would be arranged. The transmitters 5 are some kind of electro-optical converters or modulators, such as modulated lasers, providing on their output an optical signal modulated on some wavelength, which can be the same wavelength for all transmitters 7. The optical signal from a transmitter 7 is provided to the input of an associated transponder 11, in which the optical signal from the transmitter 7 is received and is transmitted on a very well defined wavelength. The output fibers of the transponders 11 are connected to an optical multiplexer 13, in which the incoming light signals are combined with or superposed on each other. From the multiplexer 13 the resulting optical signal is transmitted on an optical fibre 3 carrying signals from the considered node 1 to the receiving side of the other node. There, the optical fibre 3 is connected to an optical demultiplexer 15, in which the different wavelengths of the incoming signal are filtered out and are forwarded on optical fibers to the respective receiver 9 in an access equipment 5, the receivers 9 being optoelectrical converters such as suitable PIN-diodes.

In the link illustrated in Fig. 1, the components thereof can of course become defective and stop operating in the intended way. In particular there may be failures in the access equipment 5, in the transmitters 7 and the receivers 9, and in the transponders 11, which are all active optical elements. In order to arrange a protection against such failures a spare or standby channel must be arranged in the link. This standby channel can then be used when one of the components becomes defective. Special arrangements for switching to this standby channel must also be provided and there must also be a redundancy in the access equipment 5.

A bidirectional WDM link having such protection is illustrated in the block diagram of Fig. 2. In this link the access equipments 5 contain a 1+1 optical protection and in the nodes 1 there is a 1:3, generally a 1:N, protection of the corresponding three WDM channels, in the general case N WDM channels. Each access equipment 5 at one end, which is thus arranged for an own channel, comprises one working or ordinary optical transmitter 7 and one spare or standby optical transmitter Tx' or 7', and one working or ordinary optical receiver 9 and one spare or standby optical receiver Rx' or 9'. These spare transmitters 7' and receivers 9' can be in an operative state all the time, being supplied with power and the transmitters 7' issuing all the time the same signals as the ordinary transmitters 7.

An optical 2x2 cross-bar space switch 17 has first one of its two inputs connected to an ordinary transmitter 7 and its second input connected to the standby transmitter 7 in the pair of ordinary transmitter and standby transmitter in the same access equipment 5. In the same way, an optical 2x2 cross-bar space switch 19 has one of its two outputs connected to an ordinary receiver 7 and another one of its outputs connected to the standby receiver 7' of a pair of ordinary receiver 7 and standby receiver 7' in the same access equipment 5. A cross-bar switch has two inputs and two outputs and can be in one of two states or positions. In the bar state, which is the ordinary state of the cross-bar switches considered here, it connects a first input to a first output and a second input to a second output, making a "parallel" or "bar" connection. In the cross state, which is the state considered here when the cross-bar switches receive a control signal, it connects the first input to the second output and the second input to the first output, thus making "crossing" connections.

The WDM equipment in the node 1 uses a fourth, standby channel, in the general case a (N+1)-th channel. In the transmitter side thus a transponder 21 for the standby channel is provided, having its output also connected to the multiplexer or combiner 13 and working in parallel with the regular transponders 11. Every transponder 11, 21 will thus transmit on its own specific wavelength. In a cross-bar switch 17 on the transmitting side that output, which in the normal, bar state of the switch is connected to the ordinary transmitter 7, is connected to a regular transponder 11, and its other output, which in the normal, bar state of the cross-bar switch 15 is connected to the spare transmitter 7' is connected to one input of an optical 4:1 space switch 23, this space switch being in the generally case made for switching from one of (N+1) inputs to one output. Thus three inputs of the 4:1 switch 23 are in the normal state of the node 1 connected to a single spare transmitter 7'. Thus there is one input of the 4:1 switch 23 which is not connected to anything. In the normal operation of the node 1, in which no components are defective, the 4:1 switch 23 is in its fourth position, in which it does not receive any signals and does not transmit any signal.

At the receiving side the demultiplexer 15 is arranged for splitting the incoming signal into four individual wavelength bands, in the general case into (N+1) individual, distinct wavelengths or wavelength bands. Three of the outputs of the demultiplexer 15 are connected to that input of the respective cross-bar switch 19, to that input thereof which in the normal state of the node 1, in which no components are defective, to the ordinary receiver 9. That output terminal of the demultiplexer 15, which carries the wavelength band generated by the spare transponder 21 on the transmitting side, is connected to a 1:4 optical space switch 25, in the general case to a 1:(N+1) switch. Three outputs of this 1:4 switch 25 are connected to the other one of the inputs of the cross-bar switches 19, to that input thereof which in the normal operation of the node 1 is connected to the spare receiver 9'. The fourth output of the 1:4 switch 25 is terminated

and thus does not carry any signals anywhere. This is also the normal position of the 1:4 switch 25 in which all components in the transmitting side and the receiving side of the nodes 1 are working normally.

In the normal state thus all of the cross-bar switches 17, 19 are in their bar state and thus the signals carrying information are transmitted from the ordinary transmitters 7 to the corresponding ordinary transponder 11, via the combiner 13, the fibre link 3 and the demultiplexer 15, to the ordinary receiver 9. The output signals of the hot standby transmitters 7 passes to the 4:1 switch 23 on the transmitting side and are terminated there, since this switch is not in a position for receiving any output from any transmitter, since it is in the fourth position, in the general case its (N+1)-th position.

Now the different cases will be described which can occur when some device in the bidirectional link of Fig. 2 becomes defective.

An access transmitter 7 can become defective. This is detected by the transponder 11, which is connected to this defective transmitter 7 through the respective one of the cross-bar switches 17 and which makes this detection by finding, through a power detector 27 provided on its input terminal, that there is a loss of power on the input terminal. The power detector 27 of the transponder 11 transmits a signal to the cross-bar switch 17 which is connected to the input terminal of the transponder. The cross-bar switch 17 then switches from its bar state to the cross state. The output signal of the standby transmitter 7', which all the time transmits the same signal as the ordinary transmitter 7 in the same pair of ordinary transmitter and standby transmitter will now instead be directed to the same transponder 11 through the crossed path through the cross-bar switch 17 which has changed its position to the cross state.

For a failure of an access receiver 9, this state is detected by a signal processing circuit 29 inside the access equipment 5, which then changes the output to be delivered from the standby receiver 9' in the same pair of ordinary receiver and standby receiver by changing the position of an electric switch 31. A signal is then transmitted to the cross-bar switch 19, which is connected to the input of this pair. This cross-bar switch 19 then switches from its bar state to the cross state and thus directs the light signal from the demultiplexer 15 directly to the operating standby receiver 9' in the pair.

Also one of the regular transponders 11 can become defective. It is detected on the receiving side by the demultiplexer 15, in particular by the loss of power detected by power measurement devices 33. In the receiving side the 1:4 switch 25 and the 4:1 switch 23 are both switched to the position corresponding to the failed wavelength channel. The 1:4 switch 25 connects its input terminal to that cross-bar switch 19, which is connected to the receiver 9, which was to receive the light signal, which now has disappeared or been lost. The 4:1 switch 23 connects in the corresponding way its input terminal, which is connected through a cross-bar switch 17 to the transmitter 7 belonging to the same access equipment 5 as the receiver 9, which would have received the light signal, which

now has disappeared, to its output. Said cross-bar switches 19 and 17 are switched from their bar state to the cross state. Also the transponder 11 is turned off for the wavelength band, on which no signals are received, and the spare transponder 21 on the same receiving side is activated.

In the transmitting node there will then be a loss of power for the same wavelength band, which is sensed by its demultiplexer 15 and then also the transmitting node will be reconfigured in the same way as the receiving node. For both traffic directions the considered signal now passes from the ordinary transmitter 7, through its associated 2x2 cross-bar switch 17, which now is in a cross state, to 4:1 space switch 23 and then the signal is transmitted to the spare transponder 21 in the transmitting node, from the spare transponder 21 to the wavelength combiner 13, through a fibre 3 and to the demultiplexer 15 and from the demultiplexer to that one of its output terminals, which is connected to the 1:4 switch 25, to the correct cross-bar switch 19, which is in its cross state and then up to the ordinary receiver 9 for this channel. This case is also illustrated in Fig. 3.

The node construction illustrated in Figs. 2 and 3 can be modified in various ways. Thus, in Fig. 4 the same basic node construction is illustrated, in which the 2x2 cross-bar switches 17 connected to the transmitters 7 and the standby transmitters 7' have been omitted. Then the output signal of the ordinary transmitter 7 is directly connected to the input terminal of the respective ordinary transponder 11 and the standby transmitter 9', which always transmits the same signals as the ordinary transmitter 7 is directly connected to the respective input of the 4:1 switch 23.

For a failure of one of the ordinary transmitters 7 the transponder 11 connected to the output of this defective transmitter detects loss of power. Then this transponder 11 is turned off and the spare transponder 21 is activated. Both the 4:1 and 1:4 switches 23, 25 are switched to the position corresponding to the position of the defective transmitter. The cross-bar switch 19 connected to the receiver corresponding to the defective transmitter 7 is switched from its bar state to the cross state, so that the ordinary receiver 9 now receives a light signal from the 1:4 switch 25.

In the other node, in which the defective transmitter 7 is located, loss of power is detected by the demultiplexer 15 by the respective power monitor 33 on the output side thereof. Then also here the 4:1 and 1:4 switches 23, 25 are switched to receive or transmit respectively the wavelength channel corresponding to the channel, for which the loss of power has been detected. The cross-bar switch 19 connected to the receiver 9 is switched from its bar state to the cross state, so that the ordinary receiver 9 now receives a light signal from the 1:4 switch 25. In this side also the respective regular transponder 11 is turned off and the spare transponder 21 is activated.

After the switching has been made, the traffic for both directions now passes from the standby transmitter 7' to the 4:1 switch 23, through the spare transponder 21, through the multiplexer 13 and over the fibre link 3, in the receiving side through the

demultiplexer 15 to the 1:4 switch 25, from the respective output port of this switch to the cross-bar switch 19, which is in its cross state, up to the ordinary receiver 9.

Also the cross-bar switches 19 connected to the receivers 9 and 9' can be removed. This case is illustrated in the diagram of Fig. 5. A defective transmitter 7 is detected in the same way as for the node design of Fig. 4. Also all of the switching of the respective elements is the same. Of course no control signals can be passed to the cross-bar switches 17, 19 since there are none. Instead the redirected light signal will not arrive to the ordinary receiver 9 but to the standby receiver 9' in the respective pair of an ordinary receiver and a standby receiver.

The advantage of the designs of Figs. 4 and 5 is obviously that no cross-bar switches 17, 19 or at most only one cross-bar switch 19 is arranged in the path of light from a transmitter 7 to a receiver 9. The disadvantage is that if a transmitter 7 fails, the spare transponder 21 will be occupied and it will not be possible to use it as a standby for an ordinary transponder 11.

Another modification that is shown in the diagram of Fig. 6 is to replace the cross-bar switches 15 connected to the transmitters by an ordinary 2x2 fibre coupler 35 together with an optical on-off switch 37, the switch being connected between the standby transmitter 7' and the coupler 35. The resulting function will be the same as using a cross-bar switch 17. The advantage of this node design is that there is no cross-bar switch in the path of light after the ordinary transmitter 7. The disadvantage is that the optical power loss for light passing from the transmitters 7 is increased (-3 dB). At this location in the node this will normally be a minor drawback.

Another modification is illustrated in Fig. 7, in which each 2x2 cross-bar switch 19 connected directly to a pair of receivers 9 and 9' are replaced with four 1:2 50-50% fibre couplers 39 arranged in a fixed cross-bar function operating by power splitting, so that the output from the demultiplexer 15 always reaches both the ordinary receiver 9 and the standby receiver 9' and so that the output from the corresponding port of the 1:4 optical space switch 25 also reaches the two receivers 9, 9' in such a pair simultaneously. For a fault in an ordinary receiver 9, this will be detected by the signal detector 29 in the same access equipment 5 and then there will be an automatic change to the standby receiver 9' by changing the position of the electric switch 31. No more elements have to be switched. A drawback of this construction is an increased optical loss, about -6 dB. The advantage is that fewer electrical control lines are needed in the node.

Another modification is that no spare transmitters 7' and/or spare receivers 9' are used, see Fig. 8. Then the respective cross-bar switches 17, 19 can be replaced by 1:2 50/50% optical splitters 47, 49, so that the signal from a transmitter 7 always reaches the appropriate ordinary transponder 11 and the respective input port of the 4:1 switch 23. In the case where an ordinary transponder 11 fails, this is detected as above and the 4:1 switch 23 is then set to the respective position, so that the standby transponders 21 will

now carry the traffic.

The optical space switches, i.e. the 1:2 switches 41, 43, the 2x2 cross-bar switches 17, 19 and in particular the 1:4 and 4:1 switches 23, 25 used in the node designs illustrated in Figs. 2 - 8 can be replaced with alternative switches constructed not entirely of optical elements. The reason for introducing such alternatives is that particularly large optical switch matrices are not considered reliable. In the 4:1 switch 51 illustrated in Fig. 9 receivers 53 are arranged on the input side converting the light signals to electrical signals, which are provided to an electrical switch 55, switching the selected input electrical signal to the output, as commanded by electric control signals on lines 57. The electric signal is converted to an optical signal by a transmitter 59 using the wavelength adapted to that of the spare transponder, which thus can be omitted. The switch 61 of Fig. 9 can thus be used to replace the switch 23 and the spare transponder 21 of for example Fig. 2.

Another possibility is to use back-to-back receivers and transmitters, as is illustrated in the 4:1 switch 63 of Fig. 10. An input light signal is thus received by a receiver 64, in which it is converted to an electric signal sent to an electrooptical transmitter 65. The transmitter 65 is controlled by an electrical signal on an appropriate control line 67 and when it is activated it will transmit a light signal using the wavelength of the spare transponder. The outputs of the transmitters are all connected to an optical multiplexer, the output of which is then connected to the optical fibre 3, so that the spare transponder can be omitted. The switch 63 illustrated in Fig. 10 can be used to replace the switch 23 and the spare transponder of for example Fig. 2.

A cross-bar switch 71 to used as a switch 17, 19 shown in Fig. 2 can be designed as is illustrated in Fig. 11. The two input optical terminals are connected to optoelectrical receivers 73, which convert the light signals to electrical signals. The electrical signals are provided to a switch matrix performing 75 the cross/bar function as controlled by a suitable electrical signal on a line 77. The two outputs of the electrical cross-bar switch 75 are connected to the inputs of electrooptical transmitters 79.

CLAIMS

1. A WDM network comprising at least two nodes connected by a bidirectional link, each node comprising at least two pairs of ordinary optical transmitters receiving electrical signals and converting them to issued optical signals and ordinary optical receivers receiving optical signals and converting them to electrical signals, **characterized by** ordinary transponders, each ordinary transponder receiving the issued optical signals from only one of the ordinary optical transmitters and converting the signals to issued optical signals of a well defined wavelength band, the different wavelength bands being separate from each other, the signals of well defined wavelength bands issued by the ordinary transponders of one node being provided to an optical multiplexer or combiner combining the signals to issue them on an optical fiber connected to another node. (Figs. 1 - 8)

2. A WDM network according to claim 1, **characterized by** a spare transponder in each node, the spare transponder being arranged to receive optical signals and to convert them to issued optical signals of a well defined wavelength band, this wavelength band being separate from the wavelength bands of the ordinary transponders in the nodes, the signals issued by the spare transponder being provided to the optical multiplexer or combiner of the node combining the signals with the signals from the ordinary transponders of the node to issue them on the optical fiber, the spare transponder being arranged to receive the optical signals, which are intended to be received by an ordinary transponder, in the case of a failure of that ordinary transponder. (Figs. 2 - 8)

3. A WDM network according to claim 2, **characterized by** optical switches, an optical switch having an input and a first output and a second output, the input being connected to an ordinary optical transmitter and the first output being connected to that ordinary transponder which is arranged to receive the optical signals issued by the ordinary optical transmitter, and the second output being connected to forward to the spare transponder optical signals received on the input of the switch. (Figs. 2, 3, 7)

4. A WDM network according to claim 3, **characterized in** that each ordinary transponder is provided with an input loss detector controlling the optical switch connected to the ordinary transponder. (Figs. 2, 3, 7)

5. A WDM network according to claim 2, **characterized by** optical power splitters, an optical power splitter having an input and a first output and a second output, the input being connected to an ordinary optical transmitter to receive signals issued thereby and the first output being connected to that ordinary transponder which is arranged to receive the optical signals issued by the ordinary transmitter and the second output being connected to forward a share of optical signals received on the input to the spare transponder. (Figs. 6, 8)

6. A WDM network according to any of claims 2 - 5, **characterized by** an optical switch having a plurality of inputs, one input being arranged for each ordinary transponder and connected thereto, and further an output connected to an input of the

spare transponder, the switch being arranged to connect one of its inputs to its output in order to forward optical signals issued by an ordinary optical transmitter to the spare transponder. (Figs. 2 - 7, 9)

7. A WDM network comprising at least two nodes connected by a bidirectional link, each node comprising at least two pairs of ordinary transmitter devices and ordinary receiver devices, each pair being arranged to transmit and receive optical signals respectively on an individual wavelength, and each node further comprising a pair of a spare transmitter device and a spare receiver device, **characterized in** that the spare transmitter device and the spare receiver device are arranged to respectively transmit and receive optical signals on a fixed wavelength different from those wavelengths on which the ordinary transmitter devices and receiver devices of the node are arranged to transmit and receive respectively optical signals. (Figs. 2 - 8)

8. A WDM network according to claim 7, **characterized by** a switch connected in such a way that if one of the transmitter devices fails, its input signal is connected through the switch to the input of the spare transmitter device. (Figs. 2 - 8)

9. A WDM network according to any of claims 7 - 8, **characterized in** that each ordinary transmitter device comprises an ordinary optical transmitter and an ordinary transponder connected to the ordinary transmitter, the ordinary optical transmitter receiving electrical signals and converting them to issued optical signals and the ordinary transponder receiving the optical signals issued by the ordinary optical transmitters and converting the optical signals to issued optical signals of a well defined wavelength band, the wavelength bands of different transponders being separate from each other, and that each spare transmitter device comprises a spare transmitter and a spare transponder connected to the spare transmitter, the spare transponder being common to all spare transmitters in a node and connected to all spare transmitters and converting received signals to issued optical signals of a well defined wavelength band separate from the wavelength bands of the ordinary transponders. (Figs. 2 - 7)

10. A WDM network according to claim 9, **characterized in** that the spare transponder is connected through a switch to all the ordinary optical transmitters in a node to receive the optical signals issued by at most one of the ordinary optical transmitters. (Figs. 2 - 7)

11. A WDM network according to any of claims 7 - 10, **characterized in** that each ordinary receiver device comprises a demultiplexer or filter and an ordinary optical receiver, the ordinary optical receiver converting received optical signals to electrical signals, the demultiplexer or filter being common to all ordinary optical receivers in a node, each spare receiver device comprising the demultiplexer or filter, an ordinary optical receiver and a switching device, the switching device having outputs connected to the ordinary optical receivers and forwarding a signal from the demultiplexer or filter to at most one of the ordinary optical receivers. (Figs. 2 - 7)

12. A WDM network according to any of claims 7 - 10, **characterized in** that each ordinary receiver device comprises a demultiplexer or filter and an ordinary optical receiver, the ordinary optical receiver converting received optical signals to electrical signals, the demultiplexer or filter being common to all ordinary optical receivers in a node, each spare receiver device comprising the demultiplexer or filter, a spare optical receiver and a switching device, the switching device having outputs connected to the spare optical receivers and forwarding a signal from the demultiplexer or filter to at most one of the ordinary spare optical receivers. (Figs. 2 - 7)

13. A WDM network according to claim 12, **characterized in** that a signal which is forwarded from the demultiplexer or filter to one of the spare optical receivers has the same wavelength as that of a spare transponder.

14. A WDM network according to claim 12, **characterized in** that a signal which is forwarded from the demultiplexer or filter to one of the spare optical receivers has the same wavelength as that of the ordinary transmitter device in the pair of an ordinary transmitter device and that ordinary receiver device, comprising that ordinary receiver with which the spare receiver is included in a pair.

15. A WDM network comprising at least two nodes connected by a bidirectional link, each node comprising at least two pairs of ordinary optical transmitters and ordinary optical receivers, an ordinary optical transmitter receiving electrical signals and converting them to optical signals and issuing the optical signals to another node and an ordinary optical receiver receiving optical signals from another node and converting them to electrical signals, **characterized by** spare optical transmitters, one spare optical transmitter being arranged together with an ordinary optical transmitter in a pair, the spare optical transmitter and the ordinary optical transmitter of a pair receiving the same electrical signals and converting them to optical signals and the spare optical transmitter being arranged to issue the optical signals to the other node, if the ordinary optical transmitter fails. (Figs. 2 - 7)

16. A WDM network according to claim 15, **characterized by** first optical switches, a first optical switch being connected to an ordinary optical transmitter and a spare optical transmitter of a pair in order to forward optical signals from only one of them. (Figs. 2, 3, 7)

17. A WDM network according to claim 16, **characterized in** that each first optical switch is arranged to connect, in a first position, an ordinary optical transmitter to an ordinary transponder, an ordinary transponder converting received optical signals to issued optical signals of a well defined wavelength band, the wavelength bands of different ordinary transponders in a node being separate from each other, the optical signals issued by the ordinary transponders of one node being provided to an optical multiplexer or combiner combining the signals to issue them on an optical fiber connected to another node, and to connect, in a second position of the first optical switch, an ordinary

transmitter to a spare transponder, the spare transponder converting received optical signals to issued optical signals of a well defined wavelength band, the wavelength band of the spare transponder being separate from the wavelength bands of the ordinary transponders in the node, the optical signals issued by the spare transponder being provided to the optical multiplexer or combiner. (Figs. 2, 3, 7)

18. A WDM network according to claim 17, **characterized in** that in the first position of a first optical switch the spare optical transmitter which is connected to the first optical switch is connected through the first optical switch to the spare transponder through also a second switch, the second switch allowing optical signals from at most one spare optical transmitter to reach the spare transponder. (Figs. 2, 3, 7)

19. A WDM network according to claim 18, **characterized in** that in the second position of a first optical switch the ordinary optical transmitter which is connected to the first optical switch is connected through the first optical switch to the spare transponder through also the second switch, the second switch allowing optical signals from at most one ordinary optical transmitter to reach the spare transponder. (Figs. 2, 3, 7)

20. A WDM network according to any of claims 17 - 19, **characterized in** that in the second position of a first optical switch the spare optical transmitter which is connected to this first optical switch is connected to a respective ordinary transponder. (Figs. 2, 3, 7)

21. A WDM network according to any of claims 16 - 20, **characterized in** that each ordinary optical transmitter is connected to an ordinary transponder, one ordinary transponder being arranged for each ordinary optical transmitter, an ordinary transponder being arranged to convert received optical signals to issued optical signals of a well defined wavelength band, the wavelength bands of different ordinary transponders in a node being separate from each other, the optical signals issued by the ordinary transponders of one node being provided to an optical multiplexer or combiner combining the signals to issue them on an optical fiber connected to another node, and the spare optical transmitters being connected to a spare transponder, the spare transponder converting received optical signals to issued optical signals of a well defined wavelength band, the wavelength band of the spare transponder being separate from the wavelength bands of the ordinary transponders in the node, the optical signals issued by the spare transponder being provided to the optical multiplexer or combiner, the connection of the spare optical transmitters to the spare transponder being made in such a way that the spare transponder receives at most optical signals issued by at most one spare transmitter. (Figs. 2 - 7)

22. A WDM network according to any of claims 15 - 21, **characterized in** that all ordinary receivers of a node are connected to a single demultiplexer or filter and convert received optical signals to electrical signals. (Figs. 2 - 7)

23. A WDM network according to any of claims 15 - 21, **characterized in** that all

ordinary receivers of a node are connected to a single demultiplexer or filter and convert received optical signals to electrical signals, a switch being provided to conduct an optical signal from the demultiplexer or filter to at most one of the ordinary receivers, this optical signal having the same wavelength as that of a spare transponder.

24. A WDM network according to any of claims 15 - 23, **characterized by** spare optical receivers, one spare optical receiver being arranged together with an ordinary optical receiver in a pair, the spare optical receiver and the ordinary optical receiver of a pair converting received optical signals to electrical signals and being connected to output electrical signals to the same output terminal, so that the spare optical receiver delivers electrical signals to the output terminal, node, if the ordinary optical receiver cannot deliver electrical signals. (Figs. 2 - 7)

25. A WDM network according to claim 24, **characterized in** that all ordinary receivers of a node are connected to a single demultiplexer or filter and convert received optical signals to electrical signals, each spare receiver being connected to the demultiplexer or filter through a switch, the switch having a plurality of outputs, each output being connected to a different one of the spare optical receivers, and the switch being arranged to forward a signal from the demultiplexer or filter to at most one of the spare optical receivers. (Figs. 2 - 7)

26. A WDM network according to claim 25, **characterized in** that a signal which is forwarded from the demultiplexer or filter to one of the spare optical receivers has the same wavelength as that of a spare transponder.

27. A WDM network according to claim 25, **characterized in** that a signal which is forwarded from the demultiplexer or filter to one of the spare optical receivers has the same wavelength as that of the ordinary transmitter in the pair of an ordinary transmitter and that ordinary receiver, with which the spare receiver is included in a pair.

ABSTRACT

An optical network comprises a bidirectional link connecting two nodes (1) through two optical fibers (3). Optical output signals from optical transmitters (7) in a node are provided to transponders (11) issuing optical signals of well-defined wavelengths to a power combiner (13), from which optical signals are forwarded to the other node on the respective fiber. The network can have protection for failures of various components. Thus, a spare transponder (21) can receive the optical output signals of an optical transmitter (7) in the case of a failure of an ordinary transponder (11). The spare transponder (21) is also connected to the combiner (13). The optical transmitters (7) and receivers (9) can be duplicated by providing spare transmitters (7') and spare receivers (9'). Various arrangements can be used for connecting the output of a transmitter to an ordinary transponder or the spare transponder. For example, cross-bar switches (17, 19) can be arranged at the outputs of a pair of an ordinary transmitter and a spare transmitter and at the inputs of a pair of an ordinary receiver and a spare receiver. For a node having N-1 ordinary transmitters a N:1 switch (23) is then arranged at the input of the spare transponder (21).

(Fig. 2)

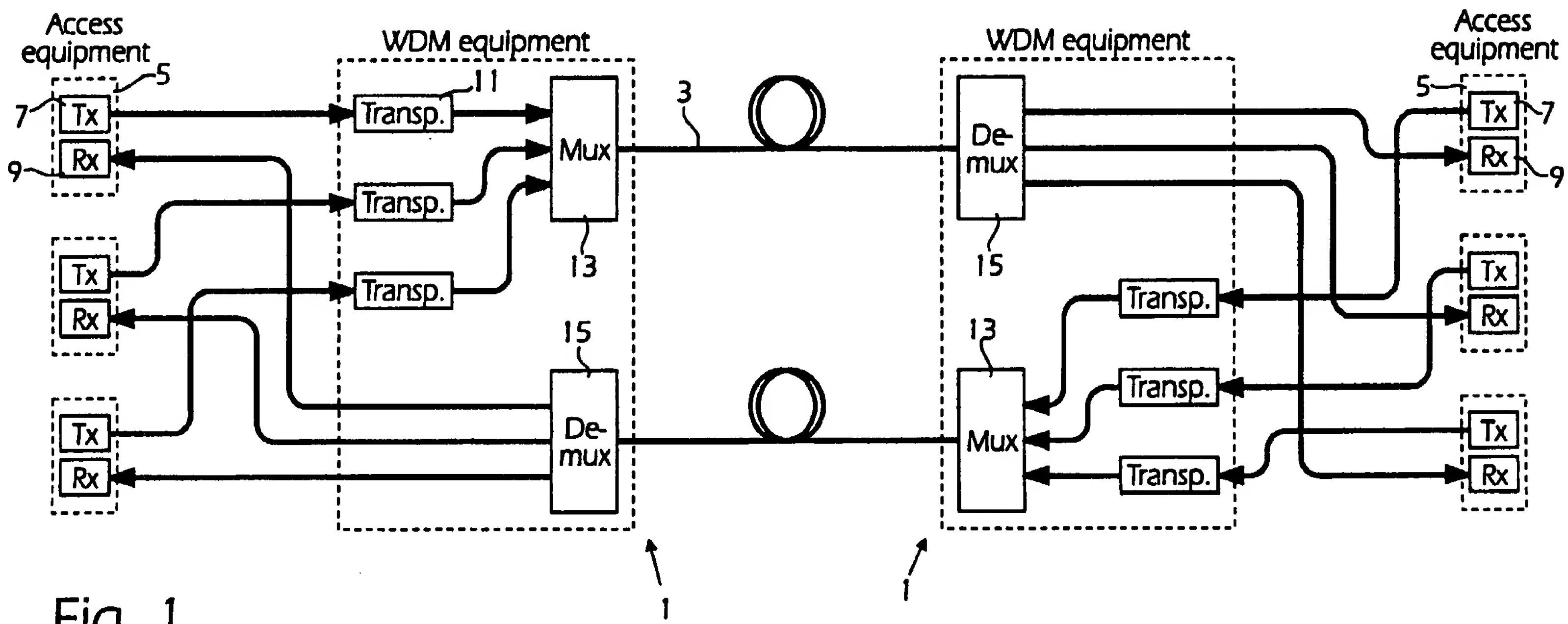
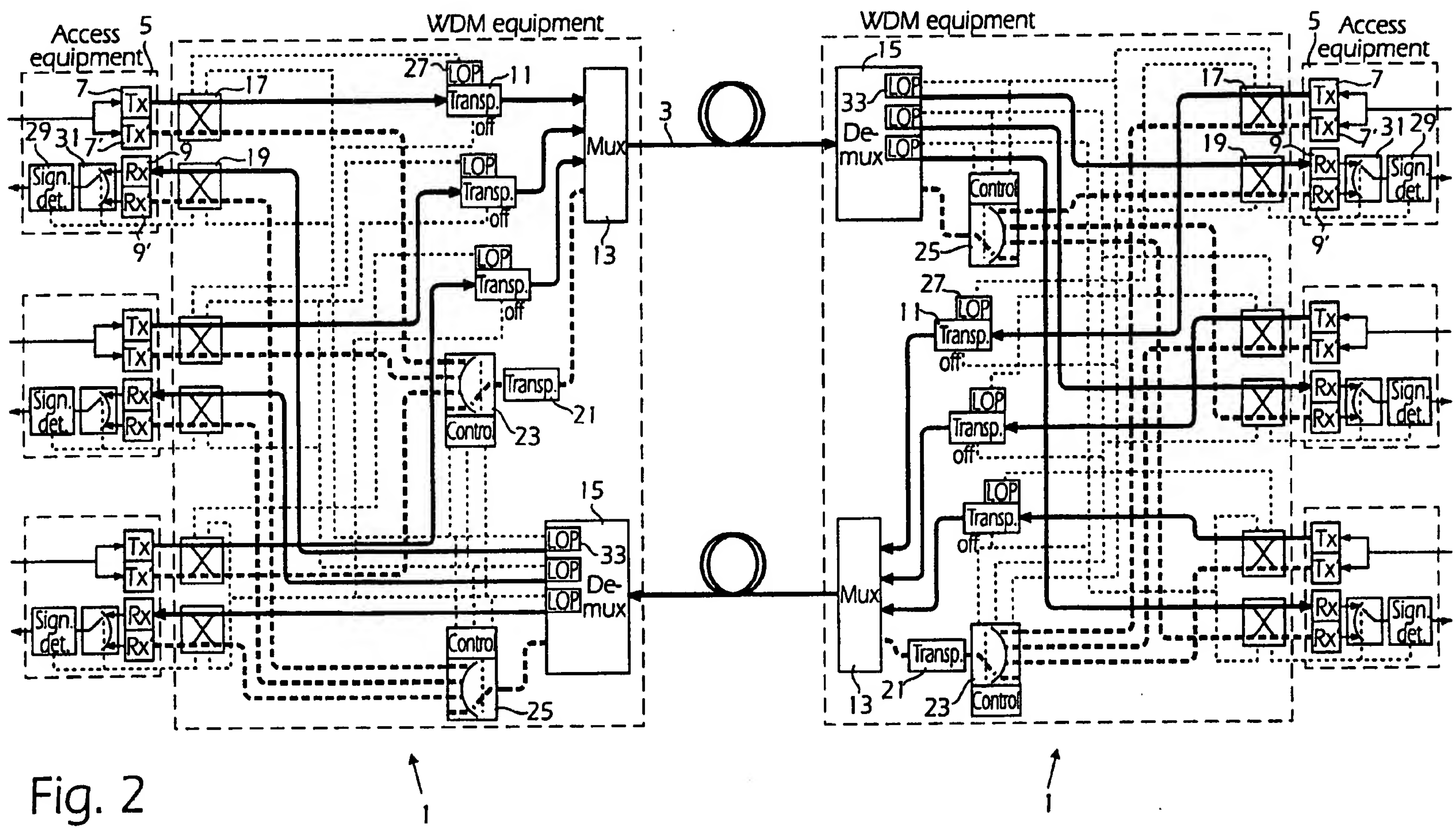
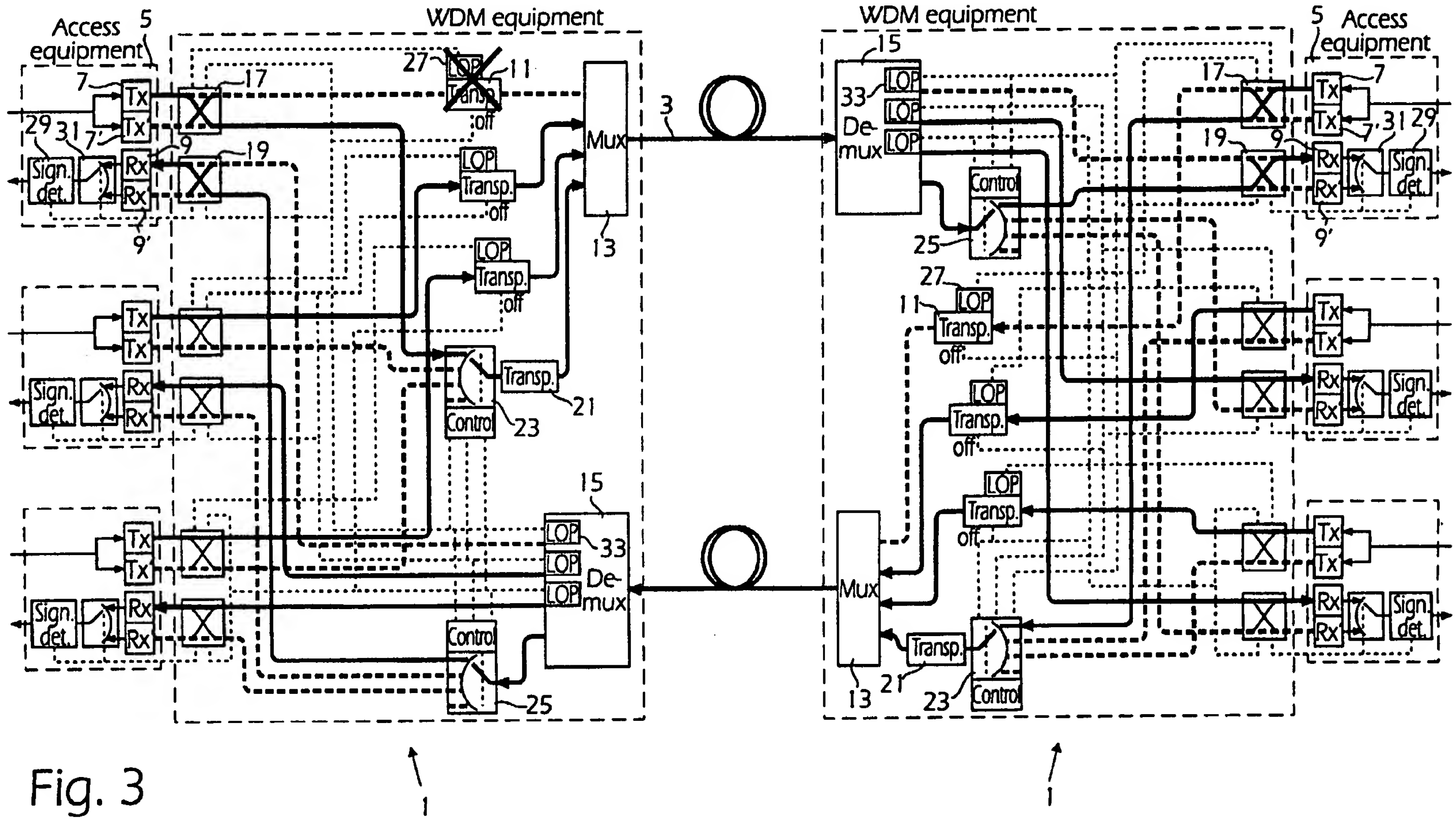

Access equipment
WDM equipment
WDM equipment
Access equipment
Tx
Rx
Transp.
Mux
De-mux
3
5
7
9
11
13
15
1

Fig. 1



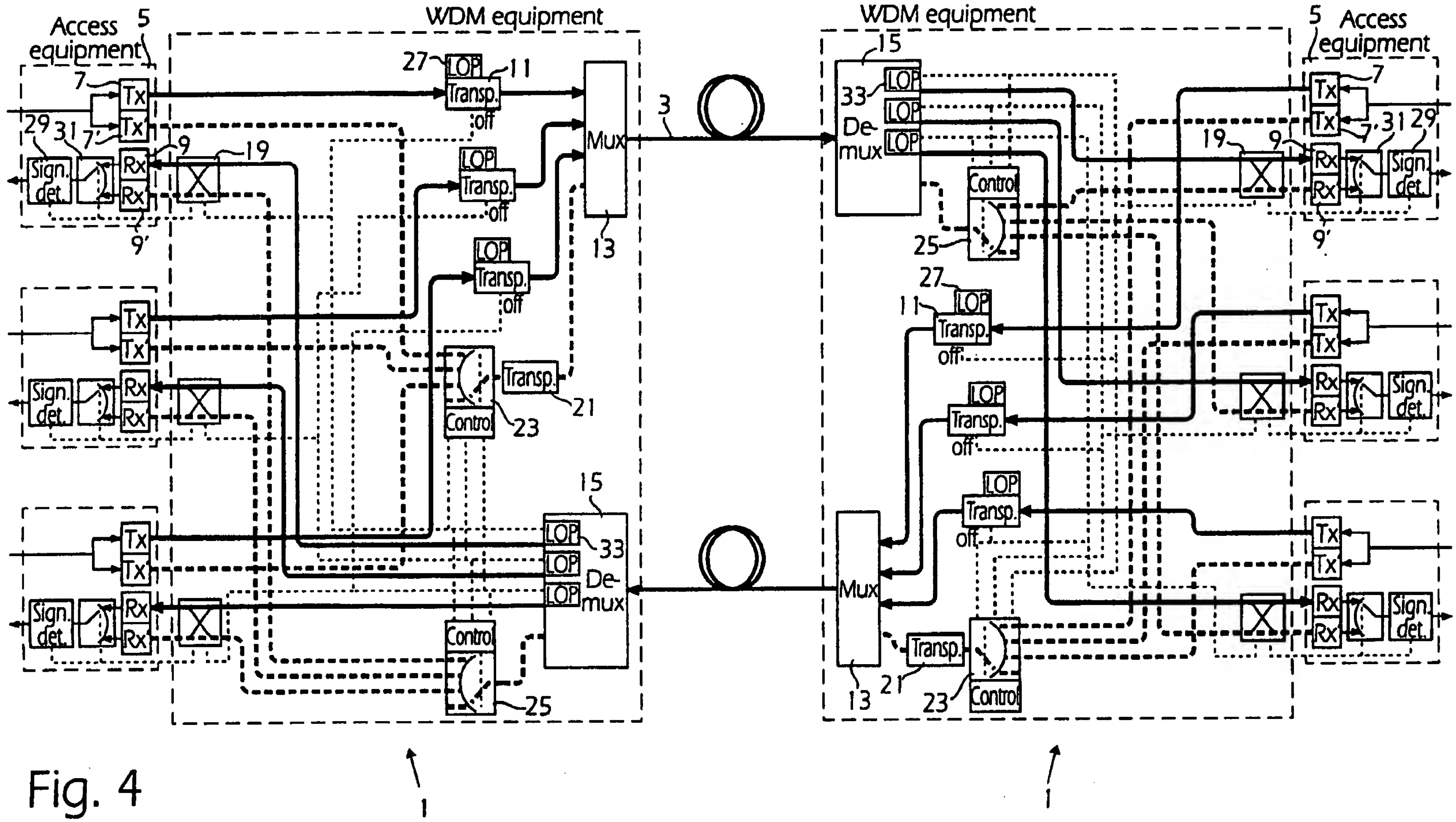
Access equipment
5
WDM equipment
7
7'
9
9'
11
13
15
17
19
21
23
25
27
29
31
33
3
Tx
Rx
Sign. det.
LOP
Transp.
off
Mux
De-mux
Control
1

Fig. 2



Access equipment
5
WDM equipment
7
7'
9
9'
11
13
15
17
19
21
23
25
27
29
31
33
3
1
Tx
Rx
Sign. det.
LOP
Transp.
off
Mux
De-mux
Control

Fig. 3



Access equipment
WDM equipment
Tx
Rx
Sign. det.
LOP
Transp.
off
Mux
De-mux
Control
Transp.

Fig. 4

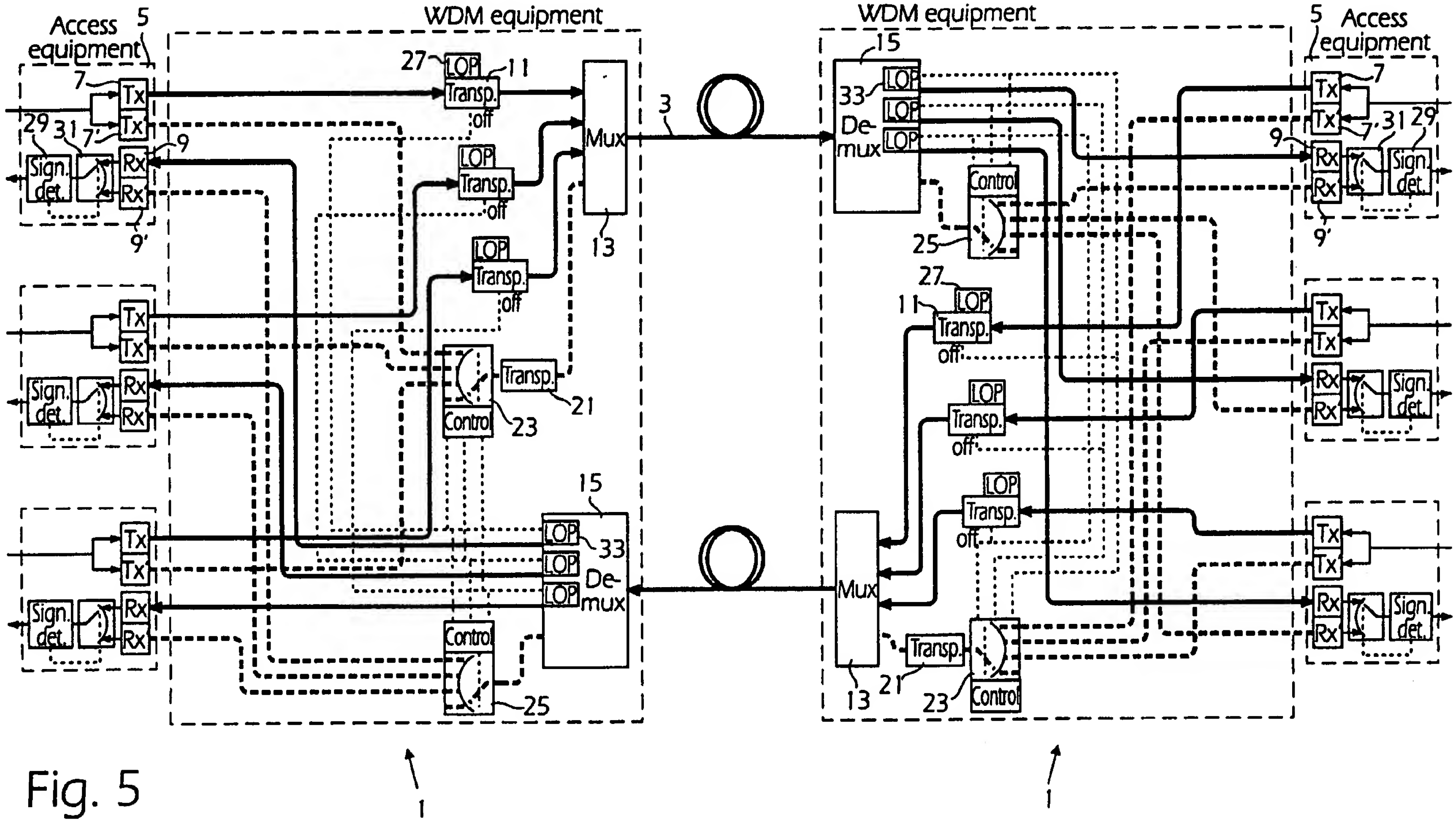
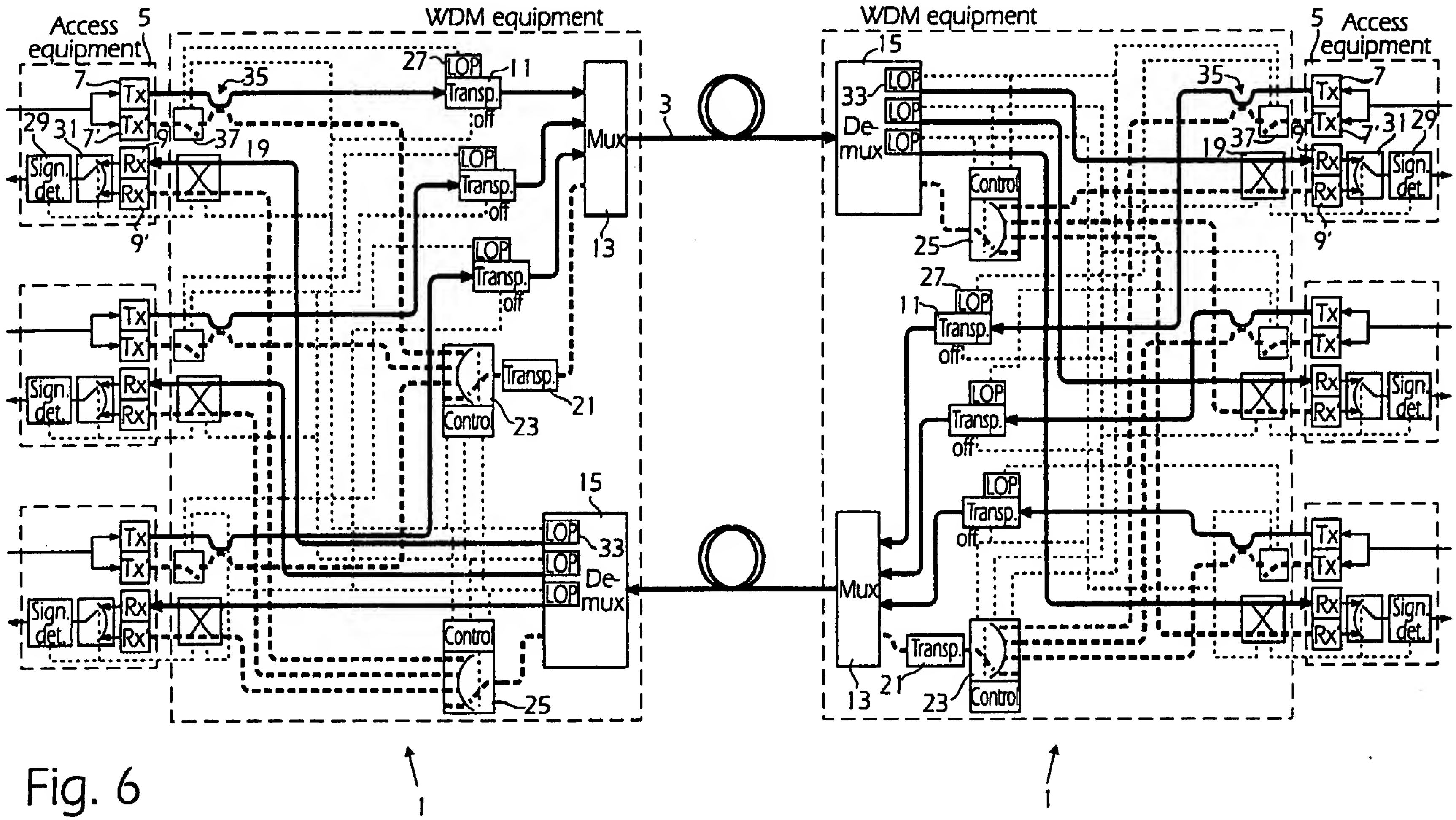
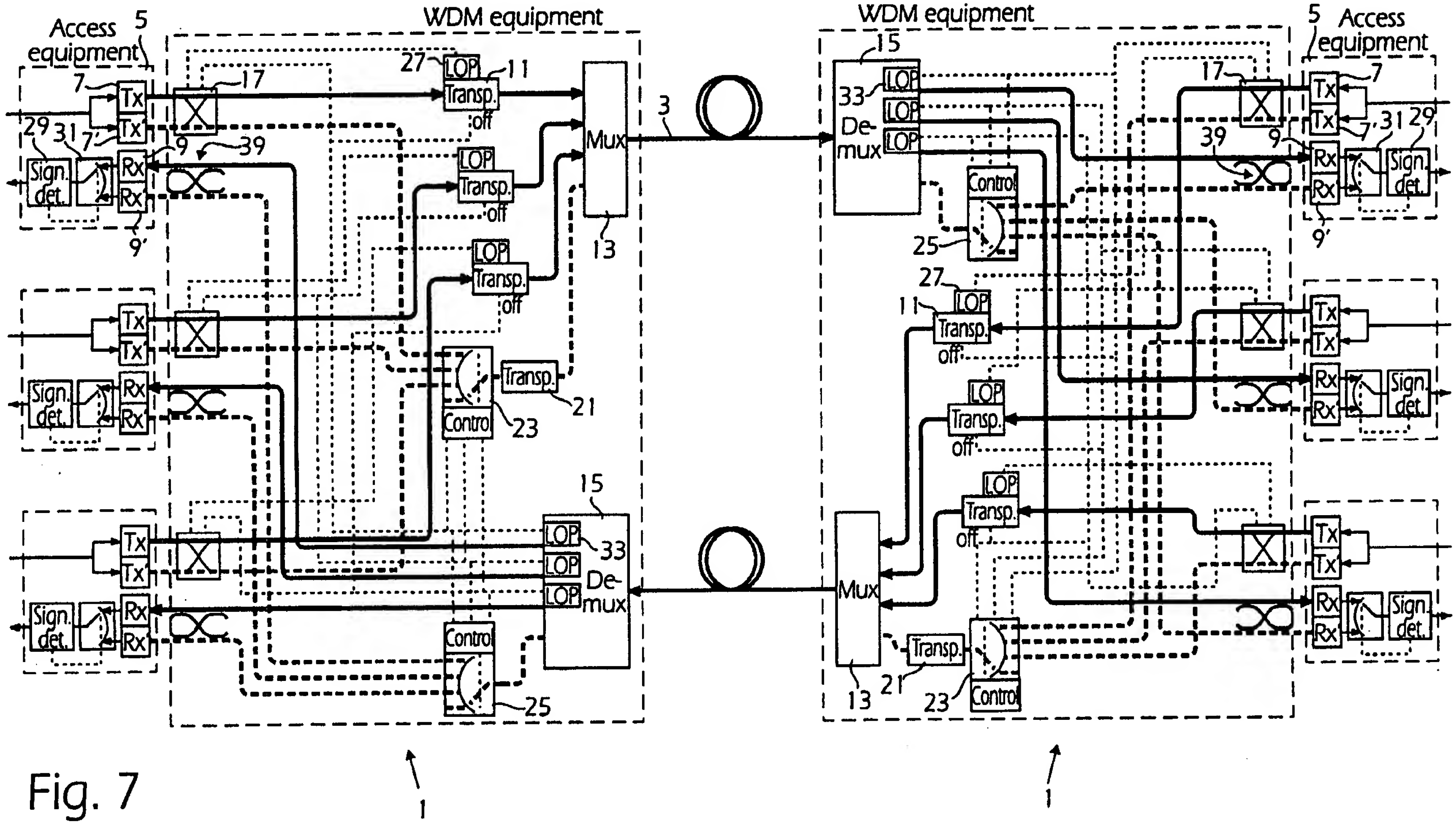

Access equipment
5
WDM equipment
27
LOP
Transp.
off
11
Mux
13
3
7
7'
Tx
Rx
Sign. det.
29
31
9
9'
21
23
Control
25
15
33
De-mux
1

Fig. 5



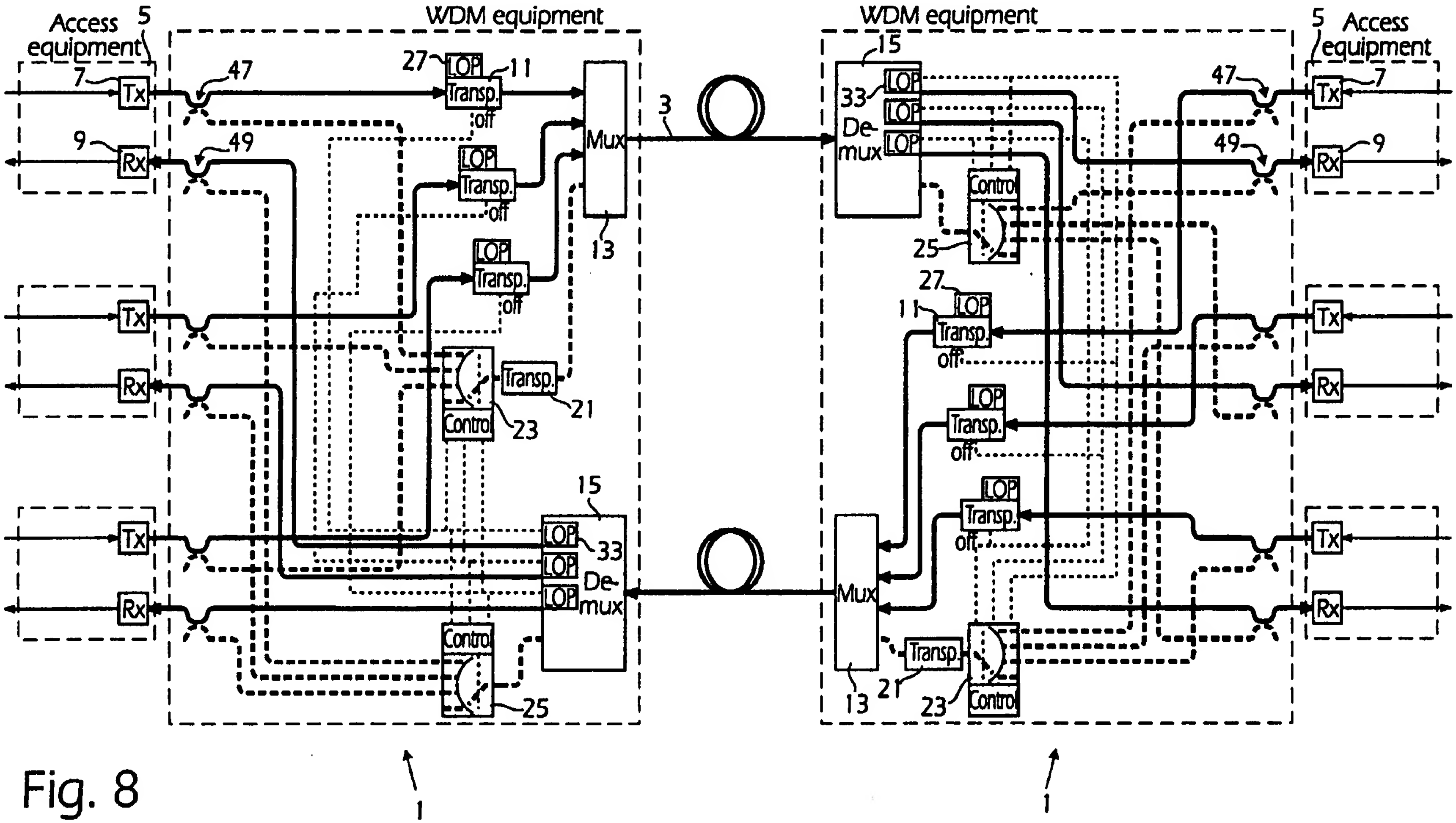
Access equipment
5
WDM equipment
Tx
Rx
Sign. det.
LOP
Transp.
off
Mux
De-mux
Control
Transp.
3
7
7'
9
9'
11
13
15
19
21
23
25
27
29
31
33
35
37
1

Fig. 6



Access equipment
WDM equipment
Tx
Rx
Sign. det.
LOP
Transp.
off
Mux
De-mux
Control
Transp.

Fig. 7



Access equipment
5
7
9
Tx
Rx
WDM equipment
47
49
27
LOP
11
Transp.
off
Mux
13
3
15
33
De-mux
Control
21
23
25
1

Fig. 8

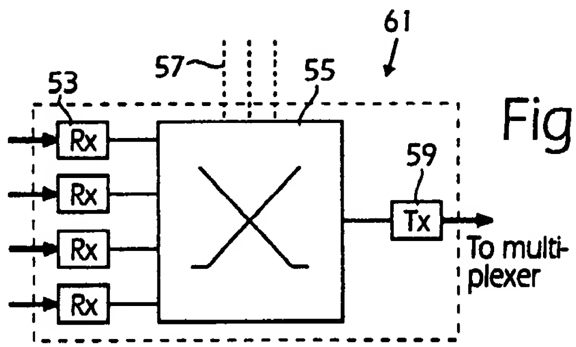


Fig. 9

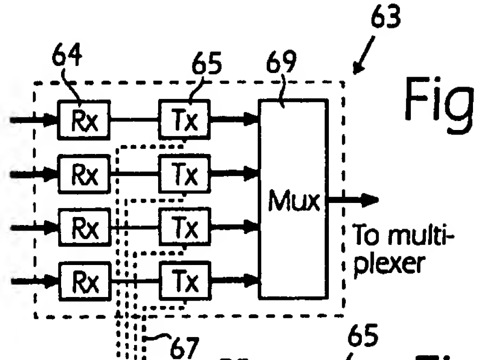


Fig. 10

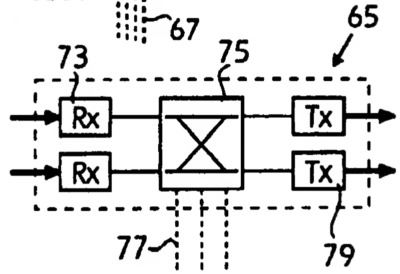


Fig. 11